National Aeronautics and Space Administration

Quantifying the role of climate variability in driving the recent acceleration of Earth's fastest glacier

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Program: FY21 SURP **Strategic Focus Area: Ocean and ice**

Objective and Approach:

The objective of this project is to **quantify the importance of internal multi-decadal climate variability in driving the recent speedup, ice front evolution, and mass loss of Jakobshavn Isbrae** (or Sermeq Kujalleq) **outlet glacier in West Greenland.** To do so, we:

- estimate the multidecadal variability of ocean and atmospheric temperatures through analysis of existing ensemble climate simulation
- emulate climate variability using statistical and machine learning approaches to produce a plausible ensemble of climate forcing in the Jakobshavn region
- perform a simulation ensemble that captures the variability of climate forcing, and compare the ensemble to the observed regional ice mass change

These experiments are designed to quantify the possible impact of internal climate variability on the recent glacier mass loss, therefore deducing the relative importance of internal variability to other sources of simulation uncertainty.

Background:

Over the last decades, many glaciers have experienced rapid acceleration and ice front retreat. Jakobshavn Isbrae, Earth's fastest glacier draining a significant fraction of the Greenland Ice Sheet, has undergone significant change over that period in response to warming oceanic and atmospheric conditions, including:

- ice speeds that have more than doubled over the past three decades.
- retreat of its ice front inland by more than 20 km
- collapse of its floating ice shelf has collapsed
- accumulated mass loss has reached more than 500 Gt (~1.5 mm of sea-level rise equivalent)

Recently, Jakobshavn Isbrae has slowed as waters in the North Atlantic Ocean have cooled. Understanding the factors that drive regional glacier changes is critical for developing projection frameworks of Greenland sea-level contribution and quantifying model projection uncertainty.

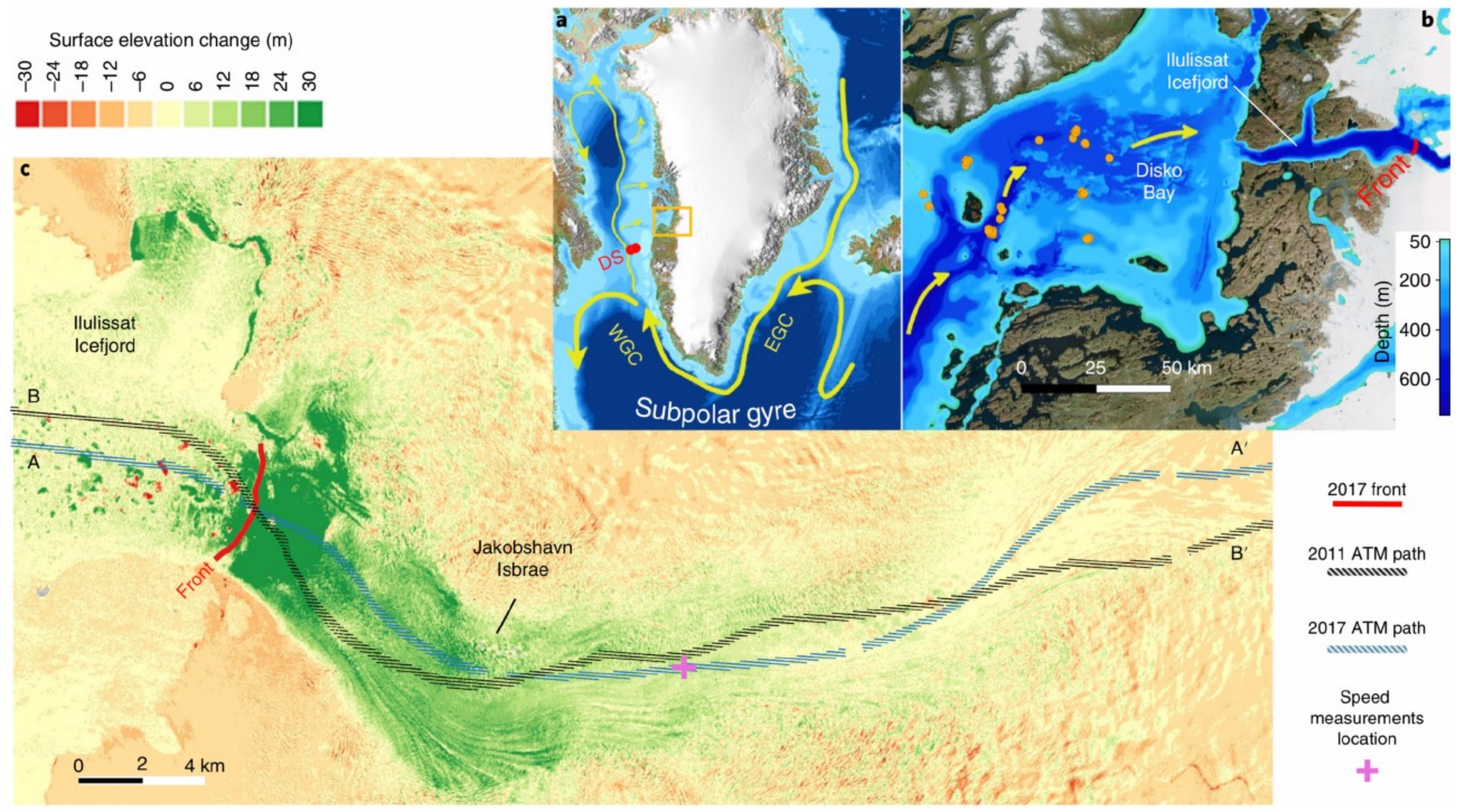

Figure 1. Ice front re-advance and ice thickening of Jakobshavn Istrae in West Greenland in 2017, happening in conjunction with ocean cooling (Khazendar et al., 2019).

Significance:

Our results highlight the large climate variability in Disko Bay that is superimposed on top of a trend of warming, and Jakobshavn Isbrae's sensitivity to shifting trends in climate forcing. This confirms the roles of the trend and variability in atmospheric and oceanic conditions in driving the evolution of Jakobshavn Isbrae's retreat.

During the past 2 years, this project has served to build stronger links between the JPL Sea Level and Ice Group and the Georgia Tech Ice and Climate Group, including multiple seminars between institutions.

Publications:

Z. Rashed, A. Robel, H. Seroussi, et al., "Disentangling the physical mechanisms linking ocean warming to the recent retreat of Sermeq Kujalleq, Greenland", in prep. for Journal of Glaciology

Results:

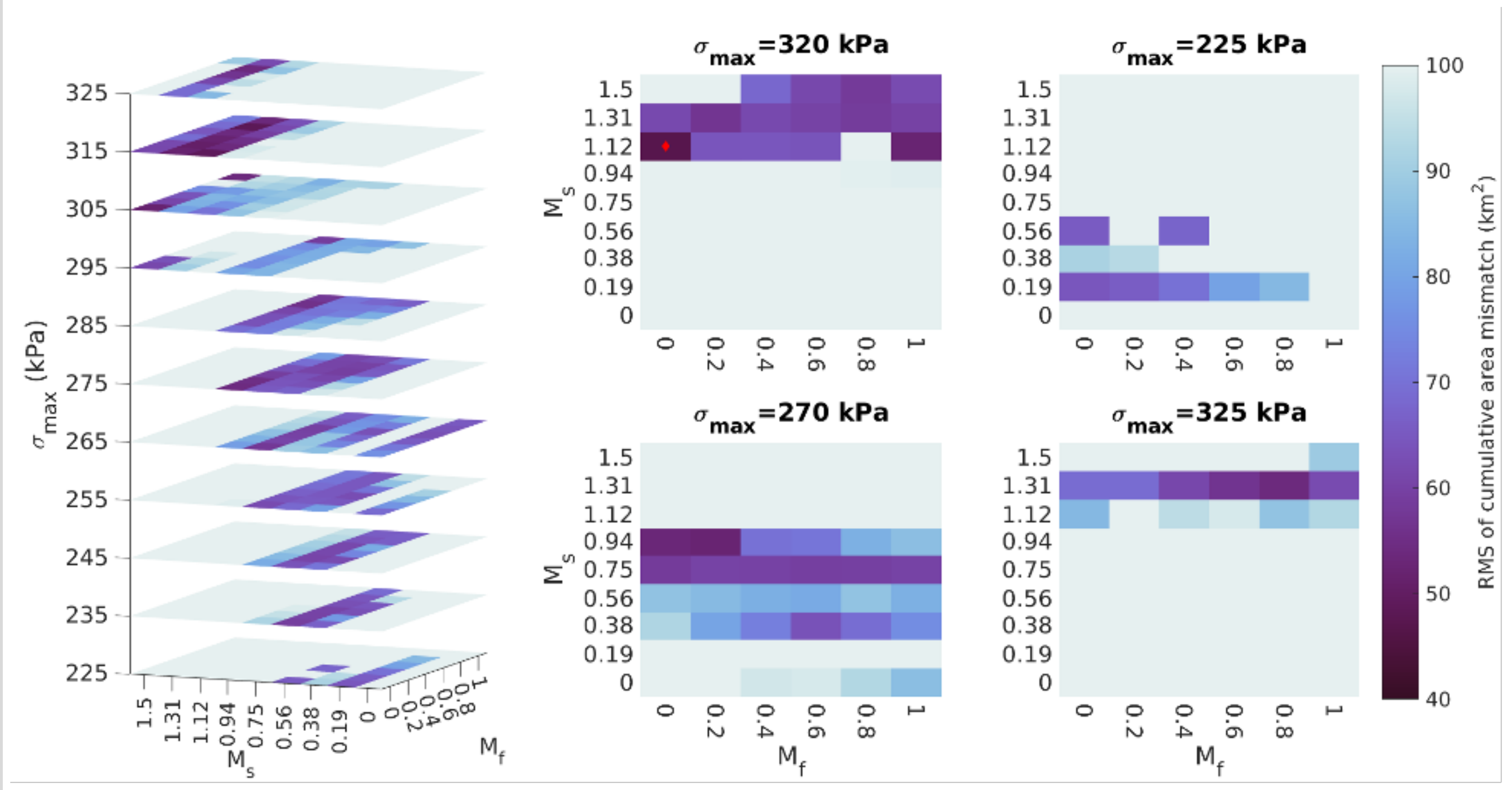

Figure 2. Root mean square (RMS) of total area discrepancy between ensemble members' and observed calving front positions for varying ice shelf melt, M_s, frontal melt, M_f, and maximum stress threshold, σ_{max}. Lower RMS indicates a closer fit between models and observations. As σ_{max} increases, larger submarine melt are required to offset the decrease in calving. The red diamond indicates the lowest RMS ensemble member analyzed in Fig.3.

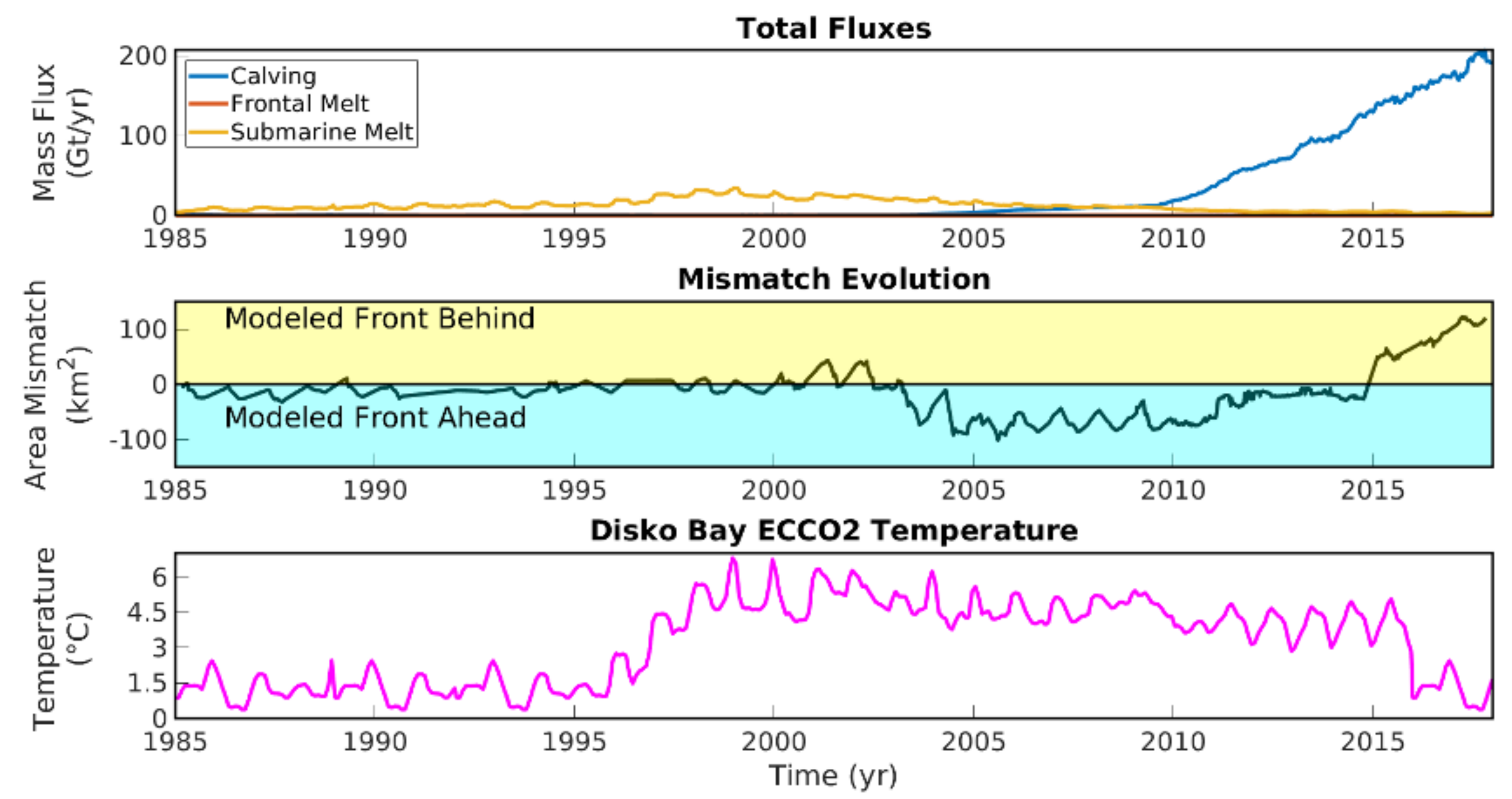

Figure 3. Top panel - total ice flux into the ocean due to calving, submarine melt, and frontal forcing. Here frontal forcing is set to 0. Middle panel - discrepancy between modeled and observed calving front positions. Our best model is able to capture the evolution of submarine-melt forced retreat better than calving-forced, as noted by the rise in mismatch as calving fluxes become more dominant. Lower panel - Disko Bay ECCO2-derived temperature used to force the retreat mechanisms.

⇒ **Glacier response is highly connected to variability in ocean forcing**. Note: From 1985-2007, calving flux is minimal, and retreat is dominated by submarine melt; from 2007 onward, retreat is dominated by a rapid increase in calving fluxes as Jakobshavn's front enters deeper bathymetry.

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